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Altitudinal distribution and species richness of herbaceous plants in *campos rupestres* of the Southern Espinhaço Range, Minas Gerais, Brazil

Distribuição altitudinal e riqueza de espécies de plantas herbáceas em campos rupestres do sul da Cadeia do Espinhaço, Minas Gerais, Brasil

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Abstract
The variation in the species richness of herbaceous plants along an altitudinal gradient was analyzed in the Serra do Ouro Branco and Serra do Ribeiro, in the townships of Ouro Branco and Ouro Preto, respectively. Plant similarity between both *serras* was also assessed. Twenty spots were sampled along a 440 m (1105 m to 1545 m) altitudinal range; at each site, herbs were collected within ten 1 m^2 plots, totaling 200 m^2. We found 101 species distributed in 59 genera and 25 families. The richest plant families in Serra do Ouro Branco were Poaceae (22 spp.), Asteraceae (14 spp.) and Cyperaceae (10 spp.), while in Serra do Ribeiro, they were Poaceae (17 spp.), Cyperaceae (12 spp.) and Asteraceae (8 spp.). Variation between the number of species and altitude was not significant. The higher number of species in Serra do Ouro Branco may be due to different local environmental factors and to the occurrence of grazing and fires. The *serras* presented a high similarity value (J = 0.44), but cluster and ordination analysis indicated the formation of two distinct groups, reflecting the importance of local factors to determine the floristic composition of neighboring areas of *campos rupestres*.
Key words: biogeography, gradient, diversity, mountains, similarity.

Resumo
A variação da riqueza de plantas herbáceas ao longo do gradiente altitudinal foi estudada em campos rupestres das Serras do Ouro Branco e do Ribeiro, localizadas respectivamente nos municípios de Ouro Branco e Ouro Preto. A similaridade entre a flora das serras também foi verificada. Foram amostrados 20 pontos num gradiente altitudinal de 440 m (1.105 m a 1.545 m); em cada ponto, as ervas foram coletadas em parcelas de 1 m^2, totalizando 200 m^2. Foram encontradas 101 espécies em 59 gêneros e 25 famílias. Na Serra do Ouro Branco, as famílias com maior número de espécies foram Poaceae (22 spp.), Asteraceae (14 spp.) e Cyperaceae (10 spp.), enquanto na Serra do Ribeiro foram Poaceae (17 spp.), Cyperaceae (12 spp.) e Asteraceae (8 spp.). Não houve variação significativa da riqueza de espécies com a altitude e a Serra do Ouro Branco apresentou um maior número de espécies. As serras apresentaram elevada similaridade entre si (J = 0,44), porém houve a formação de dois grupos distintos nas análises de agrupamento e ordenação, indicando que a riqueza de espécies em áreas relativamente próximas de campo rupestre podem estar sob influência de fatores locais predominantes.
Palavras-chave: biogeografia, gradiente, diversidade, montanhas, similaridade.

Introduction

Although Brazilian mountain ecosystems are of great ecological and economic importance, they are threatened by human activities and their biology is poorly known (Martinelli 2007). Studies on tropical mountain ranges are important to understand the processes and mechanisms that influence biodiversity and organism responses to environmental changes, as global warming (Gottfried *et al.* 1999; Lomolino 2001; Beckage *et al.* 2008).

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Variations in species richness along altitudinal gradients are relatively well studied (Hodkinson 2005). In short, two plant species distribution patterns were described for different organisms and biogeographical regions (Lomolino *et al.* 2006). The first one maintains that the number of species decreases as altitude increases (Rosenzweig 1995). This negative linear relationship was reported for different organisms, as birds (Terborgh 1977), herbivore insects (Fernandes & Price 1988; McCoy 1990; Carneiro *et al.* 1995) and plants (Givnish 1999; Jones *et al.* 2003). The second one holds that the number of species diminishes as we get closer to the extremes of the altitudinal gradient, and defines a maximum value of species richness at intermediate altitudes (Gentry & Dodson 1987; Rahbek 1997; Colwell & Lewis 2000; Lomolino 2001; Grytnes 2003). It was described for different groups of plant species (Tryon 1989; Grytnes 2003; Bachman *et al.* 2004; Krömer *et al.* 2005), herbivore insects (McCoy 1990), birds (Herzog *et al.* 2005) and mammals (Nor 2001).

Campos rupestres are found in the states of Minas Gerais, Bahia and Goiás. They are usually constituted by mosaics of plant communities, formed by a herbaceous stratum followed by perennial and sclerophyllous bushes and subshrubs occurring at altitudes between 900 and 2070 m, on great extensions of quartzitic outcrops with shallow, compact litholic soils (Giulietti & Pirani 1988; Romero 2002). The herbaceous stratum is mainly formed by species of the families Poaceae, Cyperaceae, Eriocaulaceae and Xyridaceae. The bush stratum comprises a high number of species of Asteraceae, Melastomataceae, Lamiaceae, and Velloziaceae (Giulietti & Pirani 1988).

In the southern Espinhaço Range, the *Quadrilátero Ferrífero* (Iron quadrangle) stands out by its rich deposits of mineable resources and remarkable biological diversity (Drummond *et al.* 2005). The region is distinguished by its high diversity of habitats, which may be related to edaphic peculiarities, to the characteristic mountain relief of the region and to the fact that it is located in a transition area between the Atlantic Forest and cerrado biomes (Council & Murta 2007). Among its different phytophysiognomies, we can mention forest (e.g. seasonal forests, gallery forests, cloudy forests), savanna (cerrado *sensu stricto*) and grassland (*campos rupestres* on quartzite, *campos rupestres* on canga and *campos limpos*) formations (Viana & Lombardi 2007).

The present work surveyed herbaceous plants in two *serras* located in the southern Espinhaço Range and verified if species richness diminishes with altitude. The influence of the environmental heterogeneity on the species composition of each *serra* was also assessed by analyzing the floristic similarity of the sampled places.

Material and Methods

This work was carried out in Serra do Ouro Branco (SOB) and Serra do Ribeiro (SR), located in the townships of Ouro Branco and Ouro Preto (Fig. 1), respectively. The SOB stands out as the most significant element of the southern border of the *Quadrilátero Ferrífero*. The altitude of its circa 65 ha varies from 1,000 to 1,573 m (Alkmim 1987). Located approximately 10 km to the North of the SOB, with altitudes varying between 1,270 and 1,550 m, the SR comprises a set of two smaller formations. Climate is mesothermic – Cwb (Köppen 1948), with mild, rainy summers and dry, cold winters. Mean annual temperatures vary between 17°C and 20°C and the annual rainfall records are approximately 1,500 mm (Giulietti & Pirani 1988). In the *campos rupestres* of both *serras*, the sampling places are characterized as quartzitic grasslands with or without subshrubs (Rizzini 1979), usually next to rocky outcrops, sometimes with evidence of grazing and fires.

Field expeditions were carried out between March and July 2004. Ten collection points arbitrarily defined, in an attempt to encompass the different types of habitats along the altitudinal gradient of each *serra*, were sampled; geographical coordinates and spot heights (Tab. 1) were determined using an Etrex Venture (Garmin®) GPS. Sampling was performed in ten 1 m² plots systematically distributed, at a distance of 5 m from each other along a 50 m imaginary line (Pivello *et al.* 1999), so that 10 m² were sampled at each altitudinal point, totaling 200 m². Plants were identified by comparison with specimens kept at the OUPR and BHCB herbaria (acronyms according to Holmgren *et al.* 1990) and with the help of specialists. Only the angiosperms composing the herbaceous stratum were sampled. Fertile samples were deposited at the OUPR herbarium. Botanical families are circumscribed according to the Angiosperm Phylogeny Group - APG II (APG 2003).

Analyses of covariance were performed to determine if plant species richness diminishes with
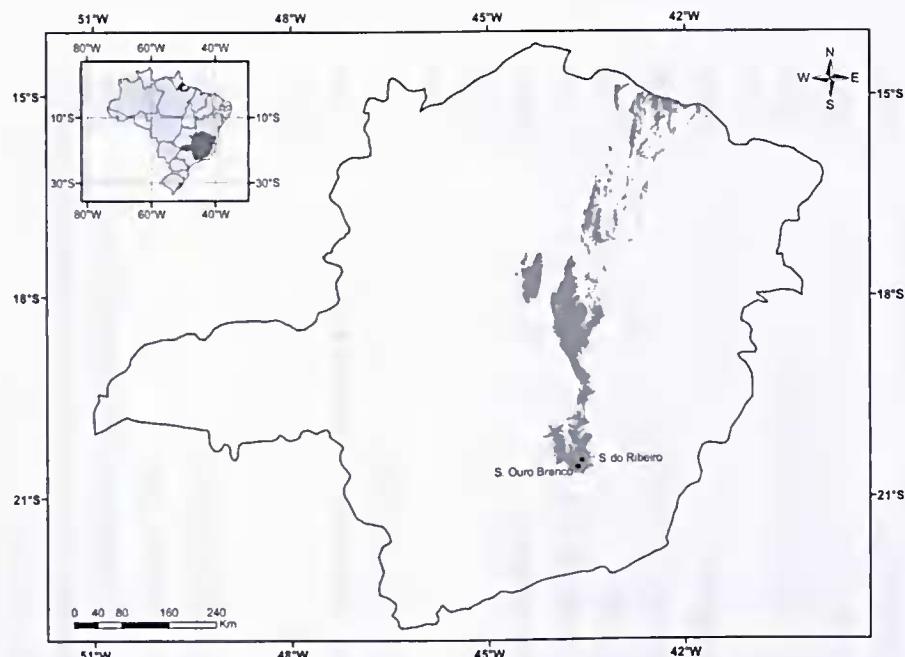
Figure 1 – Localization of the study areas in the southern Espinhaço Range, Minas Gerais, Brazil.

altitude (Crawley 2002). On our model, plant richness was the response variable and altitude (covariable) and the *serras* (categorical variable) were the explanatory variables. The analyses were performed with the statistical package R version 2.5.1 (R Development, Core Team 2005), using the 'glm' procedure, and Poisson errors were calculated through chi-square tests (χ^2). Residual analyses were carried out to check error distribution and adjust the model (Crawley 2002).

We used the Jaccard index to measure similarity between the sampling points (McCune & Grace 2002) and the relationships between them were characterized by cluster and ordination analyses based on the method of unweighted means (UPGMA), using the FITOPAC software (Shepherd 1996), and on a multidimensional scale analysis (MDS) carried out with XLSTAT data analysis and statistical solution for Microsoft ® Excel 2007.

Results

One hundred and one species distributed in 59 genera and 25 families were collected in the two studied *serras* (Tab. 2). The families with the highest number of species were Poaceae (25), Asteraceae (14), Cyperaceae (13) and Polygalaceae (9). Out of this total, 86 species grow in the SOB, 41 of which are exclusive to it, and 61 species occur in the SR, 16 of which are exclusive to it (Tab. 2). In the SOB, the families with the greatest number of species were Poaceae (22), Asteraceae (14) and Cyperaceae (10), while in the SR, they were Poaceae (17), Cyperaceae (12) and Asteraceae (8).

The species growing in the widest altitudinal range, since they found practically along the whole gradient of both places, were *Inulopsis scaposa* (Asteraceae) and *Echinolaena inflexa* (Poaceae). The most frequent species in both *serras* were: *Inulopsis scaposa* and *Lessingianthus linearifolius* (Asteraceae); *Bulbostylis paradoxa* (Cyperaceae); *Apochloa poliophylla, Echinolaena inflexa, Mesosetum loliifome* and *Paspalum hyalinum* (Poaceae); *Polygala paniculata* and *P. longicaulis* (Polygalaceae). A single sampling point presented 33 species and no exotic species were collected in the study (Tab. 2).

Although there was no significant variation in species richness with altitude for herbaceous plants (χ^2 = 2.170; p = 0.141, n = 20), a higher number of species was found in the SOB (χ^2 = 16.515; p < 0.0001; n = 20) (Fig. 2). When each of the four richest plant families were analyzed separately, the same pattern was found between the number of species and the explanatory

Table 1 – Localization, spot height and description of the collection points in the Serra do Ouro Branco (OB) and in the Serra do Ribeiro (SR).

Places	Geographic Coordenates	Description	Altitude (m)
OB1	20°30'21,8"S; 43°38'35"W	Grassland with a dense herbaceous stratum and small outcrops.	1314
OB2	20°30'6,4"S; 43°38'10,3"W	Grassland with rare bushes close to the *serra* watershed.	1232
OB3	20°30'34,5"S; 43°37'54,4"W	Grassland with a dense herbaceous stratum, close an outcrop with velozias.	1190
OB4	20°30'28,6"S; 43°37'32,8"W	Grassland with bushes and subshrubs.	1236
OB5	20°30'17,6"S; 43°39'26,6"W	Grassland with small outcrops, few bushes and small trees.	1318
OB6	20°30'1,1"S; 43°41'3,5"W	Grassland close to a riparian forest, with signs of fires and cattle grazing.	1363
OB7	20°29'12,9"S; 43°42'36,7"W	Grassland with outcrops and a large population of velozias.	1544
OB8	20°29'4,2"S; 43°42'22,7"W	Grassland close to the *serra* watershed with signs of cattle grazing.	1477
OB9	20°30'18,9"S; 43°36'28,6"W	Grassland close to a riparian forest with signs of cattle grazing.	1105
OB1	20°30'29,5"S; 43°37'5,5"W	Grassland with a large population of velozias.	1254
SR1	20°27'27,4"S; 43°36'9"W	Grassland with waterlogged areas on clayey soil.	1517
SR2	20°27'19,2"S; 43°35'7,3"W	Slope grassland with outcrops and waterlogged areas on clayey soil.	1367
SR3	20°27'41,6"S; 43°35'4"W	Grassland with few bushes close to a large outcrop and a watershed with riparian forest.	1314
SR4	20°29'1,9"S; 43°35'1,5"W	Grassland surrounded by small outcrops and velozias.	1381
SR5	20°28'19,8"S; 43°34'51,9"W	Grassland with bushes, close a small outcrop.	1318
SR6	20°28'20,8"S; 43°35'15"W	Grassland with bushes close to the *serra* watershed with great erosion.	1294
SR7	20°29'4,3"S; 43°34'45,8"W	Grassland with small outcrops close to a creek. Moist and loose soil.	1458
SR8	20°28'50,6"S; 43°34'54,1"W	Grassland with a dense herbaceous stratum, close to an outcrop and small temporary lakes.	1545
SR9	20°29'3,4"S; 43°34'5,8"W	Grassland with a dense herbaceous stratum and moist soil, between a large outcrop and a creek.	1438
SR10	20°29'7,2"S; 43°34'25,4"W	Grassland with small outcrops and a large population of velozias.	1472

Table 2 – Presence (+) and absence (-) of species of herbaceous plants along the altitudinal gradient in the *serras* do Ouro Branco and do Ribeiro, located in the Espinhaço Range, Minas Gerais, Brazil. Voucher material is represented by the collection number of R.A.X. Borges (B).

Family /Species	Serra do Ouro Branco										Serra do Ribeiro									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Amaranthaceae																				
Gomphrena scapigera Mart. (B 96)	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-
Apiaceae																				
Eryngium pandanifolium Cham & Schltdl. (B 58)	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aristolochiaceae																				
Aristolochia smilacina Duch. (B 15)	+	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Apocynaceae																				
Barjonia erecta (Vell.) Schw. (B 32)	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Asteraceae																				
Baccharis aphylla DC. (B 45)	-	-	+	-	+	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-
Calea pilosa Baker (B 37)	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromolaena decumbens (Gardner) R.M. King & H. Rob. (B 10)	+	+	+	+	+	+	+	+	+	+	+	-	+	-	-	-	-	-	-	-
Heterocondylus amphidictyus (DC.) R.M. King & H. Rob. (B 54)	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Inulopsis scaposa (DC.) O. Hoffm. (B 1)	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	-
Lessingianthus linearifolius (Less.) H. Rob. (B 21)	+	+	-	-	+	-	+	+	+	-	+	+	+	+	+	+	-	+	-	-
Mikania microphylla Sch. Bip. ex Baker (B 46)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Porophyllum lineare DC. (B 31)	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	+	+
Richterago radiata (Vell.) Roque (B 40)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stevia lundiana DC. (B 39)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lessingianthus psilophyllus (Gardner) H. Rob. (B 71)	-	+	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenocephalum megapotamicum (Spreng.) Sch. Bip. (B 35)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eupatoriae sp1 (B 108)	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-
Vernoniae sp1 (B 88)	+	+	+	+	+	+	+	+	-	-	-	-	+	-	-	-	-	-	-	-

Family /Species	Serra do Ouro Branco										Serra do Ribeiro									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Burmanniaceae																				
Burmannia bicolor Mart. (B 131)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Convolvulaceae																				
Ipomoea procumbens Mart. ex Choisy (B 69)	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Evolvulus aurigenius Mart. (B 70)	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyperaceae																				
Bulbostylis jacobinae (Spreng) Lindm (B 114)	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-
Bulbostylis junciformis (Humb.Borpl. & Kunth.) C.B. Clarke (B 111)	-	-	-	-	-	-	+	-	+	-	-	-	-	+	-	-	-	-	-	-
Bulbostylis capillaris (L.) C.B. Clarke (B 90)	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-
Bulbostylis paradoxa (Spreng.) Lindm. (B 3)	+	+	-	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	-	+
Bulbostylis scabra (Persl.) C.B.Clarke (B 7)	+	-	-	-	+	-	-	-	-	+	-	-	+	-	-	-	-	-	+	-
Lagenocarpus rigidus (Kunth) C.B. Clarke (B 130)	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Lagenocarpus tenuifolius (Kunth) C.B. Clarke (B 62)	-	-	-	-	+	-	-	-	-	-	+	+	+	+	+	+	+	+	-	+
Rhynchospora consanguinea Boeck. (B 120)	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-	+	-	+	+
Rhynchospora lapensis C.B. Clarke (B 118)	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	+	-	-	-	-
Rhynchospora pilosa (Kunth) Boeck (B 121)	-	-	-	-	-	-	-	+	+	+	+	+	-	+	+	+	+	+	+	+
Rhynchospora setigera (Kunth) Boeck. (B 123)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Scleria virgata Stench. (B 52)	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-
Scleria cuyabensis Pilg. (B 53)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Droseraceae																				
Drosera montana A. St-Hil. (B 84)	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-
Eriocaulaceae																				
Paepalanthus freyreissii (Thumb) Koern. (B 117)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Paepalanthus pubescens var. chapadensis (Koern.) Ruhl. (B 119)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
Paepalanthus sphaerocephalus Ruhl. (B 97)	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-
Syngonanthus caulescens (Poir.) Ruhl. (B 132)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+

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Family /Species	Serra do Ouro Branco										Serra do Ribeiro									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Fabaceae																				
Galactia martii DC. (B 126)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Stylosanthes capitata Vog. (B 91)	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Zornia diphylla (L.) Pers. (B 86)	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-
Gentianaceae																				
Curtia diffusa Cham. (B 109)	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Schultesia gracilis Mart. (B 102)	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	-
Iridaceae																				
Sisyrinchium alatum Hook. (B 9)	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-
Sisyrinchium vaginatum Spreng. (B 59)	+	+	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Trimezia juncifolia Klatt. (B 22)	+	+	-	+	+	+	+	-	+	+	-	-	+	-	-	-	-	+	-	-
Trimezia lutea (Klatt) R.C. Foster (B 78)	-	+	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Lamiaceae																				
Hyptis nudicaulis Benth. (B 43)	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lentibulariaceae																				
Utricularia amethystina Salzm.ex A.St.Hil. (B 82)	-	-	-	+	-	-	-	+	-	-	-	-	-	+	+	+	-	-	-	-
Utricularia flaccida A. DC. (B 133)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Utricularia gibba L. (B 103)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Melastomataceae																				
Tibouchina hieracioides Cogn. (B 28)	-	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Orchidaceae																				
Habenaria rupicola Barb. Rodr. (B 93)	-	+	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Epidendrum sp1 (B 27)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orobanchaceae																				
Buchnera lavandulacea Cham. & Schdlt. (B 29)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Family /Species	Serra do Ouro Branco										Serra do Ribeiro									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Poaceae																				
Apochloa euprepes (Renvoize) Zuloaga & Morrone (B 94)	-	+	-	+	-	-	-	-	-	+	-	+	-	-	+	-	+	-	-	-
Apochloa poliophylla Renvoize & Zuloaga (Zuloaga & Morrone) (B 42)	+	-	+	+	-	-	+	+	+	-	+	+	-	+	+	+	+	-	+	+
Aristida recurvata Kunth (B 20)	+	-	-	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Aristida torta (Ness) Kunth (B 47)	-	-	+	-	-	-	-	+	-	-	+	+	+	+	-	-	-	-	-	-
Axonopus brasiliensis (Spreng.) Kuhlm. (B 17)	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Axonopus canescens Ness ex Trin. (B 61)	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Axonopus chrysoblepharis (Lag.) Chase (B 13)	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Axonopus fastigiatus (Ness) Khulm. (B 25)	+	+	+	+	+	-	-	+	-	-	-	-	+	-	+	+	+	-	-	-
Axonopus pressus (Ness ex Steud.) Parodi (B 79)	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Echinolaena inflexa (Poir.) Chase (B 4)	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+
Mesosetum loliiforme (Hochst. ex Steud.) Chase (B 5)	+	+	+	-	+	+	+	-	+	+	-	+	+	+	+	+	-	-	-	-
Paspalum hyalinum Ness ex Trin. (B 2)	+	-	+	+	+	+	+	+	-	+	+	+	-	+	+	+	-	+	-	-
Paspalum polyphyllum Ness ex Trin. (B 18)	-	-	-	+	-	-	+	+	+	-	-	-	-	-	-	+	-	-	-	-
Schizachyrium sanguineum (Retz.) Alston (B 100)	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Schizachyrium tenerum Ness. (B 67)	-	-	-	-	-	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-
Sporobolus metallicolus Longhi-Wagner & Boechat (B 34)	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Steinchisma decipiens (Ness ex Trin.) W.V. Br. (B 87)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Thrasyopsis repanda (Ness ex Trin.) Parodi (B 74)	-	-	-	-	-	-	+	+	+	-	+	-	+	-	-	-	-	-	-	-
Trachypogon spicatus (L.f.) Kuntze (B 81)	+	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	-	-	-
Trachypogon vestitus Anderson (B 14)	+	-	+	-	+	-	+	-	-	-	+	-	+	-	-	-	-	-	-	-
Tristachya leiostachya Ness. (B 11)	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
Poaceae sp1 (B 23)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Poaceae sp2 (B 44)	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Poaceae sp3 (B 73)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Poaceae sp4 (B 65)	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Polygalaceae																				
Polygala bryoides A.St-Hil. (B 66)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygala cuspidata DC. (B 70)	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Family /Species	Serra do Ouro Branco										Serra do Ribeiro									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Polygala filiformes A. St.-Hil. (B 51)	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygala longicaulis Humb.Borpl. & Kunth (B 129)	+	+	+	+	+	+	+	+	-	-	+	+	-	+	+	+	-	-	-	-
Polygala paludosa A.St. Hill. (B 60)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygala paniculata L. (B 41)	-	-	+	+	-	-	+	+	+	+	+	+	-	+	+	+	+	-	-	+
Polygala radlkoferi Chodat. (B 110)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Polygala rhodoptera Mart. ex A.W.Benn. (B 48)	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygala sp1 (B 16)	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubiaceae																				
Galianthe angustifolia (Cham. & Schltdl.) E.L. Cabral (B 19)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spermacoce verticillata L. (B 75)	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
Spermacoce suaveolens (G. Mey.) Kuntze (B 68)	-	-	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-
Spermacoce neotenuis Govaerts (B 72)	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
Declieuxia cordigera Mart. & Zucc. (B 6)	+	+	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Psyllocarpus schwackei K. Schum. (B 38)	-	-	+	+	-	-	+	-	-	+	-	-	-	-	-	-	-	+	+	-
Solanaceae																				
Schwenckia americana L. (B 95)	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Turneraceae																				
Turnera oblongifolia Cambess. (B 56)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Verbenaceae																				
Lippia sericea Cham. (B 55)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Xyridaceae																				
Xyris graminosa Pohl ex Mart. (B 113)	+	-	-	-	+	-	+	+	-	-	+	+	-	-	+	+	+	-	-	+
Xyris trachyphylla Mart. (B 12)	-	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-

variables, but, again, there was no significant variation in species richness with altitude: Asteraceae (χ^2 = 3.708; P = 0.054; n = 20), Cyperaceae (χ^2 = 1.081; P = 0.299; n = 20), Poaceae (χ^2 = 1.9702; P = 0.160; n = 20) and Polygalaceae (χ^2 = 0.554; P = 0.457; n = 20). Nevertheless, the number of species of families Poaceae (χ^2 = 3.741; P = 0.05; n = 20), Asteraceae (χ^2 = 10.563; P = 0.001; n = 20) and Polygalaceae (χ^2 = 6.252; P = 0.01; n = 20) was significantly higher in the SOB, whereas the number of species of Cyperaceae (χ^2 = 4.681; P = 0.03; n = 20) was higher in the SR.

Forty-five species (44.5% of the total) were sampled in both *serras*, whose similarity was high (J = 0.44), although the cluster and ordination analyses yielded two distinct groups (Fig. 3 and Fig. 4). The cluster analysis showed that contiguous points on the altitudinal gradient tend to be more similar, mainly in the SR, whose samples presented higher similarity values than those of the SOB.

Although the MDS analysis showed an organization similar to that of the UPGMA, it revealed different relationships between some points, i.e. points 1 and 2 of the SR and point 8 of the SOB; and the points 7, 9 and 10 of the SR (Fig. 4). The highest similarity value is between points 5 and 6 of the SR (J = 0.61), while points 9 and 10 of the SR grouped outside the set of the two *serras* (Fig. 3 and Fig. 4).

Discussion

The total herbaceous richness recorded in this study is similar to that reported in other floristic surveys in *campos rupestres* (Giulietti *et al.* 1987; Stannard 1995; Pirani *et al.* 2003; Zappi et al. 2003; Conceição & Pirani 2005; Viana & Lombardi 2007). However, these results are probably underrated because the sampled area was small and the field work was only carried out in one climatic season of the year, so that it does not take seasonal variations into account. The higher species richness found for families Poaceae, Asteraceae and Cyperaceae is also corroborated by previous work (Giulietti *et al.* 1987; Safford 1999; Filgueiras 2002).

The absence of exotic species at collection points shows that few disturbances affect the studied place, despite of the presence of cattle and the occurrence of frequent fires, especially in the SOB, where populations of *Melinis minutiflora* P. Beauv. and *Hyparrhenia rufa* (Nees) Stapf. grow along the highway that crosses it. The occurrence of fires increases the probability of intrusion of invasive African grasses as *Melinis minutiflora*, *Urochloa decumbens* Stapf. and *Megathyrsus maximum* Jacq. (Pivello 1999).

Although the geographical proximity and the similar orogeny of the two *serras* imply similar climatic conditions, geology and biogeographical history of the species, the SOB presented higher richness of herbaceous plants than the SR. A possible explanation is the effect of grazing and fires on the plant community structure of grassland vegetation (Howe 1994), since, in the SOB, the
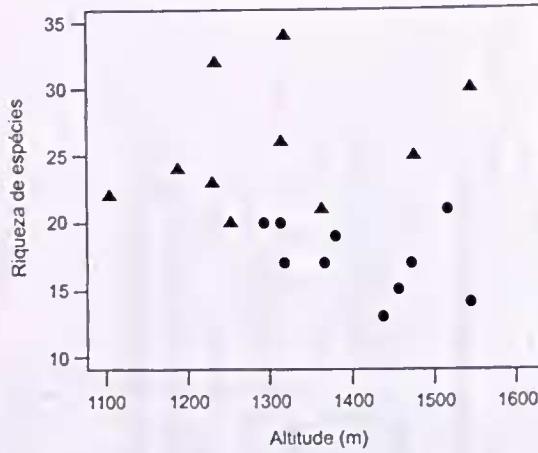
Figure 2 – Variation in herbaceous species richness according to altitude (χ^2 = 2.170; p = 0.141, n = 20). Serra do Ouro Branco (▲) and Serra do Ribeiro (●).
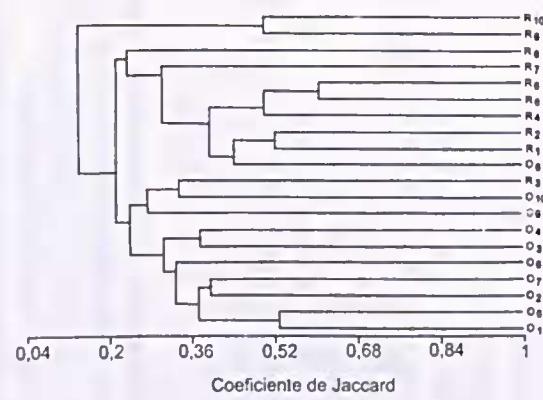
Figure 3 – Floristic similarity dendrogram based on Jaccard index among the 20 sampled points of both *serras* ($O_{1\text{-}10}$ = Serra de Ouro Branco, $R_{1\text{-}10}$ = Serra do Ribeiro).
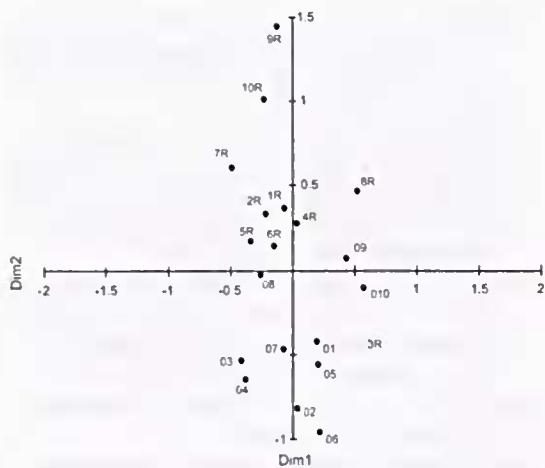
Figure 4 – Multidimensional analysis of the similarity values between the 20 sampled points in the two *serras* (O_{1-10} = Serra de Ouro Branco, R_{1-10} = Serra do Ribeiro), resulting from 10,000 repetitions (Kruskal (1) stress = 0.146).

presence of cattle and a more fires is frequently observed during the dry season.

Herbaceous species composition, mainly in natural grassland formations, has been found to present modifications related to the intensity and to the historical time of cattle grazing (Pucheta *et al.* 1998; Olff & Ritchie 1998). When comparing samples of a same area impacted by large grazers in eastern Australia, McIntyre *et al.* 2003 verified that those with medium disturbance intensity presented higher plant richness as compared to samples with little or much disturbance, which they explained by a decrease in competition and an increase in regeneration.

Along the altitudinal gradient, local factors can be more important than regional ones to determine the occurrence of species (Pausas & Austin 2001; Herzog *et al.* 2005). In this context, the facts that almost 30% of the total species occur in a single sampling point and that different species richness was found between samples at similar altitude suggest that the communities can be influenced by local factors or present a great natural variation in their species composition, with high *â*-diversity values (Lieberman *et al.* 1996). Again, one should keep in mind that the result interpretation is partial and restricted, due to the small sample size. In addition, the higher number of species of families Burmanniaceae, Cyperaceae, Eriocaulaceae and Gentianaceae in the Serra do Ribeiro is related to favorable local characteristics, as the presence of slopes with moist or soaked soils, a typical environment for given species of these families, as *Burmannia bicolor* Mart., *Rhynchospora consanguinea* Boeck. and *Syngonanthus caulescens* (Poir.) Ruhl.

According to Sano & Almeida (1998), *campos rupestres* often shelter single species clusters, whose presence is conditioned, among others factors, by soil moisture. In the Espinhaço Range, seasonality is evident, with heavy cloud cover during the winter, which causes high moisture, sporadic rains and a lot of dew, so that some regions have a waterlogged soil all year round (Giulietti & Pirani 1988).

The absence of pattern in species richness variation as altitude increases in both *serras* reflects the heterogeneity of the studied vegetation, which suggests the need of studies on the influence of local environmental and biological factors on the distribution of herbaceous plants, such as the availability of nutrients or water in the soil and competition or facilitation, respectively (Mallen-Cooper & Pickering 2008). The Espinhaço Range is a low altitude, very fragmented formation, which implies a small influence of macro-scale factors along the altitudinal gradient (Carneiro *et al.* 1995) as, for instance, climatic changes and the formation of different habitats (Whittaker *et al.* 2001).

Furthermore, the proximity between the sample points and the differences in elevation ranges and distances between them should also be considered to explain the absence of an altitudinal pattern. Nonetheless previous studies carried out on broader altitudinal ranges presented consistent variations in organism distribution, which resulted in a statistically significant relationship between species richness and altitude (Gottfried *et al.* 1999; Kessler 2000; Jones *et al.* 2003; Grytnes 2003; Bachman *et al.* 2004).

Since the *serras* presented a high number of species (44.5%) in common, the formation of the two groups observed in the UPGMA and MDS analyses probably reflects the different occurrence of species at the sample points of each *serra*, which, in turn, have peculiarities similar to insular systems in the determination of species richness (Conceição & Pirani 2007). The higher similarity found between contiguous SR samples is probably due to the low species richness variation between them, since great part of the species of this *serra* grow in various sample points.

Nevertheless, despite the small area sampled at each point, the marked difference between points 9 and 10, in the SR, may be related to their isolation in the landscape. In addition, the occurrence of species in specific places and the concentration of species in a single sampling point (Tab. 2) and the presence of different species richness between samples at similar altitude (Fig. 2) point out the importance of local factors in the species composition found, which contribute to the formation of mosaics in *campos rupestres* (Conceição & Pirani 2005).

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